Abstract

Polymers' mechanical characteristics are insufficient for many structural applications because of their inferior strength and stiffness properties when compared to those of ceramics and metals. As a result, to increase mechanical characteristics and expand structural applications, polymers are frequently reinforced with strong but costly and environmentally unsustainable synthetic fibers. In the past three decades, scientists and researchers have shown a great deal of interest in using natural fibers as reinforcing materials in polymer composites due to its advantages such as low cost, ease of availability, light weight, and high specific properties. In addition to the above benefits, natural fibers are also biodegradable and causes less wear and tear to the machining tools.

Despite the natural fibers' appealing characteristics, their usage in a variety of structural applications is limited. Natural fibers are hydrophilic in nature, which is responsible for improper interfacial interaction of fiber and the polymer matrix, as well as swelling of the fiber, resulting in the poor mechanical performance of the natural fiber reinforced polymer composites. Physical (plasma treatment, ozone treatment, laser treatment, etc.) and chemical (alkali, coupling agent treatment, etc.) treatments of the fibers, as well as matrix modification like the addition of nano-particles into the polymer matrix, can be used to overcome these obstacles. Chemical treatment methods are typically based on the use of reagent functional groups capable of reacting more effectively with the chemical constituents of the natural fiber and removing impurities and non-cellulosic materials from the fibers. As a result, this surface modification technique aids fiber bonding with polymeric matrices. However, most of these surface modification techniques are harmful to the environment as well

as to the person handling those chemicals and this will negate the very purpose of using natural fibers as reinforcement.

Against this background the present experimental research work has been carried out to modify the surface of natural fibers with various eco-friendly chemicals in order to minimize hydrophilicity and enhance the strength, crystallinity, and surface roughness of the fibers so that the fibers can have efficient bonding with the polymer matrix. The complete experimental investigation is subdivided into four broad areas focusing on surface modification of the natural fibers, physical and thermal characterization of the surface modified fibers, fabrication of the natural fiber reinforced epoxy composites and the investigation of water absorption, mechanical and tribological properties of the composites.

The first phase of experimental investigation primarily deals with the usage of eco-friendly chemicals to modify the natural fiber surface. This research work involves the application of three different types of natural fibers namely hemp, sisal and jute. Hemp fiber was surface treated with sodium carbonate and hydrogen peroxide. Sodium hydoxide, glutamic acid, combination of alkali and glutamic acid, stearic acid and sodium citrate were used as chemicals to modify the sisal fibers' surface. Jute fiber surface was chemically modified with sodium hydroxide, sodium carbonate and sodium bicarbonate. In addition to the use of various chemicals, the hemp fiber surfaces were also coated with biodegradable polymers like Polylactic acid (PLA) and Polyhydroxybutyrate (PHB) to improve the fiber's compatibility with the polymer matrix. This offers an innovative approach to fiber surface modification other than chemical treatment.

The second phase deals with various physical characterization (SEM, FTIR, XRD) and thermal characterization (TGA/DSC) techniques employed for the evaluation of surface roughness, chemical modification (functional groups), crystallinity and thermal properties of the natural fibers under investigation. Scanning electron microscopy (SEM) was used to investigate the morphological properties of the fibers, which demonstrated that the chemical treatment eliminated the contaminants from the fibers' surface. The reduction of hemicellulose and lignin contents of the fiber was confirmed by Fourier transform infrared (FTIR) analysis following chemical treatments. X-ray diffraction (XRD) analysis showed an increase in the crystallinity index of the surface modified fiber. Thermal stability of the treated fibers showed a slight reduction as revealed by Thermogravimetric analysis (TGA) and Differential scanning calorimetry (DSC).

The third phase involves the fabrication of various epoxy composites reinforced with natural fibers. Hemp/epoxy, sisal/epoxy and jute/epoxy composites were manufactured with the help of simple hand lay-up technique. After the fabrication of the composite plates, samples for various mechanical, water absorption and tensile tests were prepared according to the ASTM standards.

The fourth phase deals with the investigation of water absorption, mechanical (tensile, flexural, impact, interlaminar shear strength and micro-hardness properties) and tribological properties (wear and friction) of natural fiber reinforced epoxy composites. The experimental results revealed that both chemical treatment and polymer coatings of the fibers have resulted in improvement of water resistance and mechanical properties of the composites. Tribological test results also revealed that the surface modified fiber composites have improved wear and frictional properties in comparison to untreated fiber composites. Fractured and wear surfaces of the specimens were examined using Scanning Electron Microscope (SEM) to get insight into the composite's fracture behavior and to better understand the fiber/matrix adhesion.